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CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

FILED

PRIORITY DATE

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

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In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38s, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 45, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

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A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft ld.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 rounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein P_c is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

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- 1. A device for expanding a metallic liner inside a conduit which 1. device comprises a shaft element, an expanding die member attached to said 2 shaft element, said die member comprising a movable liner-forming member 3 positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member 6 from said shaft, and a constant force spring member positioned on said shaft 7 8 to contact said expander member and to maintain said expander member against 9 said liner-forming member, whereby said liner-forming member is urged against 10 said liner by a substantially constant force.
- 1 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said 2 conduit to expand said liner: a cylindrical shaft element, an expanding die 3 4 member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to 5 6 contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said 7 8 shaft, and a constant force spring member positioned on said shaft to contact 9 said cone member and to maintain said cone member in contact with said arm 10 members, whereby said arm members are urged outwardly by a substantially n constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 4. The device of Claim 3 wherein said compression means comprises a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

 sleeve-like element connected to said movable bearing plate member and

 slidably positioned on said shaft and a member connected to said shaft to

 limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
- 1 7. A device for installing an expanded metallic liner in a conduit 2 which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed 3 circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably 6 positioned on said shaft between said shaft and said arm members to urge said 7 arm members outwardly from said shaft; a plurality of slender columns, each 8 having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lover bearing plate member, 9 10 each slidably positioned on said shaft and contacting opposite ends of said 11 columns; limiting sleeves attached to each of said bearing plate members 12 and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply 13 14 a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the 15 16 axial travel of said bearing plate members is limited; said column members . 17 transmitting their buckling load to said arm members to urge said arm members 18 outwardly with a substantially constant force.

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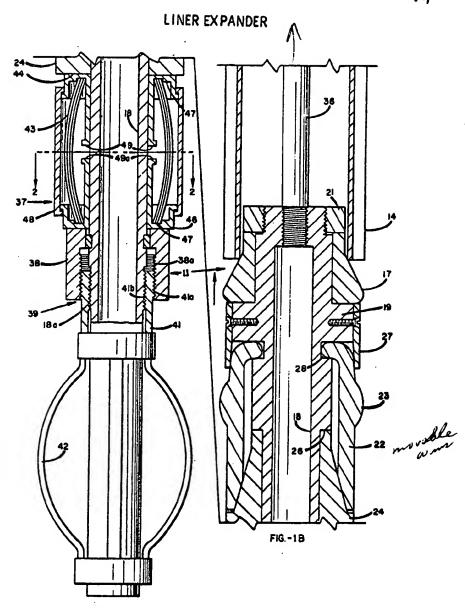
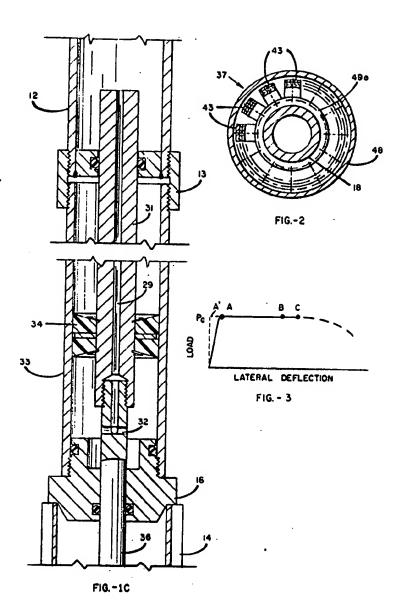


FIG.-1A



Sorry, the requested images for patent number 736288 are unavailable.

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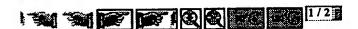
I CLAIM

In A device for expinding a schallic liner hashes a consist which device compcious a shaft element, on expending the motor object to said shaft closure, stid die number comprising a movelle liner-forming number goaldined on said shaft and being cadally movelle in respect those of the context said liner, as expender morber alliably positioned on said shaft between said shaft and send said die number to move said liner-forming number from said shaft, and a constant liner spring number positioned on said stariff to context said expenses under against the context said expenses under a said to sainthin shid expenses member against said liner-forming number, whereby said liner-forming number to unyou against said liner by a substantially constant force.

2. In a device for installing an expended metallic liner in a
2 conduit therein an expending site is moved through a liner positional in said
3 conduit to expend said liner: a cylindrical start alesent, an expending site
4 conduct to expend said shart; said the emptor comprising a plusality of arm
5 members disposed around said shart; and being physicals extensily therefrom to
6 context said liner, a cone member alightly positioned on said shart between
7 cond shart and said are members to copy said arm numbers colourelly from said
8 sharts, and a constant force agring number positioned on said starts to context
9 cond cone number and to maintain said come number in context with said arm
10 numbers, whereby said age tembers are urged outpartally by a substantially
11 comment force.

3. The favoire of Claim & shareds, said constant force spring contercomprises a planning of columns disposed around said shaft, a first bearing
plants member and a second bearing plate scatter, each of said bearing plate
members contenting opposite onts of said columns, at least one of said tearing
plate numbers being movebly positioned on said shaft and being in contacts
while said come number, stop means commerted to said staff to limit the acid,
travel of said newhole bearing plate number along said shaft, and compression
mesons for uniquidizing a internal defication in said columns.

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- . A. The device of Claim 3 wherein each compression communicates a \$1000000000 nurse expensive and appring number and said shaft.
- 5. The device of Hain 3 wherein said atop means comprises a alassa-like element commented to said speakly plants senter and stitutely positioned on said shaft and a scatter commuted to eald shaft to like the broad of said element.
- 6. The device of thata 3 warrais sold column have a measurpaire arous-meeting, the width being greater than the thickness, and bearing the maker flow mount to the dissolver of sold shaft.
- 7. A device for installing at expended ustallis lings in a cominit which comprises a cylindrical shaft classifity on acquainty dis newton measured on maid shally said the sensor comprising a plantility of any so-bare disposed resticily around the outside of said shaft and budge pivotable outmaily therefrom to contact the liner; a scalest expending states slidely hise upper or exchange are him bon thate hims seemed disch to best brong re ortherety from said shafts a plurality of element colu paving a long reutingular communication and disposed streamentially about said chaft; an upper bearing plate mesher and a larger bearing plate mesher) each slidely positioned on said mart and contecting opposite onto of said mej limiting alsores uttended to each of still tearing plats meabure and alidably positioned so said statts a shoulder number on said shafts a string load to said solumns unid shouldes being sugageable with the limiting sizers semucted to entd looks bearing plate mester, whereby the exist trevel of said bearing plate members is limited said column resolute broassitting their bugiting look to said arm numbers to urgs said arm grabers enteredly with a substantially constant force.

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My investion will be better understood by returness to the following description and the measuremying drawings whereim:

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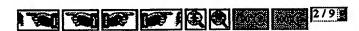
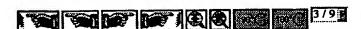




Figure 2 to a sectional view of the apparatus of Figure 1A tabes at

Figure 3 is a typical plot of applied lock versus beliaction for the constant force spring device of the Levention.

Referring to the drawings, Figure 14 is the bottom portion of a liner expending tool for one in installing a motallic liner is a well, while Figure 19 Libertroics the middle section of such a tool and Figure 35 teprements the upper serbics of the tool. The sayanding tool il is ableaded to stantant well toking 15 by empling 15 out, typically, may be lowered from the surress through a well ensing (not shown) to a point in the series at which it is desired to install a metallic liner. Before inserting the test into the well, an elemented vertically corrupted liner is fabricated from mild steel, or other suitable mileshie meterial, is placed on the tool. The engrapted liner is ecoured in position by contact at its upper end with a cylindrical shoulder masher 16 and, ot the lower and by contact with a first-stage expansing die 17 in the form of a trumonted circular core shieb serves as a firststage expending the in the second baretestier described. The expanding the to fixedly obtained to a controlly located, elongated mylimizical bollow shaft lô which forms a portion of the body of the tool. he shows, the expending 640 17 is held in place between a lower shoulder 19 and collar 21 threaded outo the shelt. A plurality of movehile arms 49, preferably provided with outserfly calarged portions 85 sear the top; are disposed in the form of a cylinder nd shaft 16. The enlarged purbless of the scan 25 eyes being moved outvarily employ the liner to purfore the final step of expending the surregard. .. himer into a enteriorisally sylintrical shape. The are numbers of ore proceedly stituted to the staff so as to be movehle outwartly Iron the shaft by a tapared expending number 26 although positioned on the shorts to serve as a sec expender. The equience of the number 2h, as shown, mover upwardly along the shaft to sugage with the area and more than outwardly. Advantageously, the inside surfaces of the area 62 and the ordered carriers of expending member 25 form setting sentions, typically categoral is shape. The expension of the arm members is somirabled by the condition of the member 20 rhich moves upwardly





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until it contacts elected 25 provided on the chaft. As member it wows in a domestrily direction area 22 fall insurally towark the shaft. The expending area 22 are held to place on the shaft by colleg 27 and circular grooms 20 recorded on the chaft.

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In operation, the liner setting tool is essential at the surface, so described shore, and a glass cloth saturated with a restance material may be empted around the corrugated take to form the hiner. The assembly is lovered the restaurant to provided to political rod 31, through ports 52 and into splinder 35 consected to the upper soil of the shoulder 16. Upon the application of finid pressure to the cylinder, the piston 34 second to polished red 31 nowe nder 33. As shown, rot 36 normerts polithed rot 31 and shaft ed the first-stage expending die 17. West the piston % is meantly through the splinder 33 the expending die 17 pest the secondfamilie well of the casing in which it is being installed. Poritioned on the ding member 24 is a communit torce spring member 37 which is employed to mys the emptyding number against the emphating mass 22 with a substantially session force. The force exerted against the ext seebers being substantially sometant, the force transmitted through the arm meters to the limy and to the sering will be substantially accordant so that either sticking of the tool is the casing or repture of the caring is precluded. Of course, the three product by the spring menter is prescluted so that the friction





forces between the tool and the liner and the presence exerted against the oneing are emistained at predetermined safe levels. The constant force spring manher ensures that the contact pressure between the liner forming purities 25 of the sons 22 is great ecough to provide the Soviced Safermation of the Sakter, whate recognitive degrees to the saning or to the tool.

The equators force spring samper 77 is blickly nounted on the shall all end hald between the expending alsoant 25 and a cylinarical lower checkler samper 35 forcing a portion of a differential serve alsoant 39 which branches the hooling on syring number 37 to chart number 10. The differential serve alsoant comprises shaft number 15 as the certific of unish are one note threads like, the lower chemister number 35 provided with female threads 55s and whichle number 51, provided with threads the end 51s are threads seen the lands, respectatively, to suggest with threads on the shaft and the shoulder. On two cots of threads are source, such as square, multiple square, or done threads, to withstand very high lands and tifter in pitch so that shoulder 35 is sound appearily on the shaft 15 when the shaft 1s revolved relative to thinkle 51. The shoulder 35 is sound appearily on the shaft 15 when the shaft 16 by splines 55 so that at can alide longitudinally, but it is not free to robute on the shaft. Finally attached to the lower and of the thinkle is a friction number, such as but appears to the shaft is except the thinkle against to the lower and of the inside will of the antipit to occurs the thinkle against toolation with respect to the shaft. Frederishly, the direction of the deciliar number threads 35s, with the pitch, or land, or threads 16s is slightly greater than the of literals 35s, with the pitch rettle bring slows to unity. To this summer, clock-vine resolution of the shart relative to the thinkle senses shoulder search 35 to alwans upwerd alightly and a cooperation load is convict upwerly on spring alasment 37 to usual vertical dissector and five and literaction threads inch aquere threads an a chaft approximately 1.7-inch outside dissector and five and literaction of the shart relative to the thinkle space.





Constant force spring element IT comprises unions element by, atmatageonally committing or a plurality of elongated column dispoted around short 18. Upper bearing plate marker by in in content with the apper ends of the anisons end is although positioned on what's if to tresourts the force of the ageing longitudinally against the better end of expendes sendor. It. Lower bearing plate number his contects the lower and of the column and is neved specially along the short by lengthedized neverset of these seculder 30 on a result of revolving differential series almost 39. Greaves by any provided in such of the bearing plates, to form on upper case and a lover case, into which the costs of the column are inserted. These grooves may be shaped to content with the shape of the column code it seatest. A cover his may be employed to smalled foreign matter from the spring mechanism and to protect

A needs for limiting the deflection of the column to required. Although the column element functions in a build consistent, application of spondal to many sense the state of the spondal to the purpose. Therefore, a pair of stops by each its are provided for this purpose. As shown, the stope are rigidly connected to the bearing plates, and, in affect comprise upper and lower limiting alseres positioned to the shaft to alide longitudinally thereon. The code of the stope may move toward, or may frue, each other as the load on the spring number varied. Lower slaves again a prevented from moding dates by loads absolder 35 semmented to the shaft 18. However, the spacing between the sade to mash as to limit the longitudinal travel of the bearing plate eachers as they move together to prevent permanent deformation of the column alament 53. Various alternative mans for preventing senses to the column alament 53. Various alternative mans for preventing senses to the column alament as a stope, or the cover 18 provides with satisfact counters may be suplayed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column clement 43 may be arranged exceed the shart 18, which as shown here forces a purition of the body of the spring Service, with sude of the columns fitted in the reces 57. The solumns may be

- 6 -

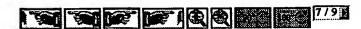




ritted closely together as shows, or may be spared around the race, with separaters used between them to metatate the desired spacing. The rember of construction. For example, the eleminant ratio of the column may be exist widely, sat the column sole say be round, flat, first or hinged. The preferred construction is a thin, element column with tousdest ands, free to move within the races shaped to the scownists of the column train. Materials which may be extincted this property supposed for the column are or order. Materials which may be extincted train—shronium stainless when and loss alloy steals, chronium and michal-shronium stainless when me persons appear have allique, such as generator because providing attisfactory symbolium properties. Typically, the individual columns are of long reviewagater cross-certion, with the width bring greater than the thickness, and arranged so that the wider face of the unisant fe moral to the dimentar of the shart. Thus, with surfacient consensation loading, the columns backles, and band shout the sain having the loant someth of inertia, e.g., outwartly may from the shart 15.

For example, a group of columns O.167-inch thick by O.575-inch wide by 10.626-inches long, with the anis required, were fabricated from i.f.S.I. \$350 steel, questabed and draws at 575°F. Buth column was found to require a critical compression leading of \$50 pounds in order to buckle the entum. After buckling, the columns were found to have a very filet spring characteristic, as shown in Figure 7, therein Polis the critical buckling load and point 0 represents the lead and deflection at which the wirese in the extreme fibers of the spring ubaracteristic curve is described by ourse 04'ABC. Actually, the curve is described by ourse 04'ABC. Actually, this curve is described by ourse 04'ABC. Actually, this curve is described by CAD due to friction in the system. Points a deal is represent typical straing limits, Oaks, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flaxing system are not moticipated, a working atrees just below the stress may be held to less than the endurance limit of the meterial of momentum time. In the above-manticond easis, the lateral minimation was limited to

- 7 -





approximately one inch, at which the longitudinal deflection was approximately 0.225 inches. From ears deflection to the assisted deflection, the \$50-pound loading was found to be substantially constant.

In mosther test a spring device was built, as down, employing 80 columns, each having a critical buckling load of 1250 posses. The internal declaration was limited between 0 and about 1.00 inches by supergrantely positioning the stope. Upon compressional loading, the spring element buckled of echatamically 25,000 posses and from a longitudinal deflection of 0.00 instead (making) to stook 0.15 inches the lend reserved substantially at 25,000

Of causes, in designing a spring elevant as above it in advantagements obtain the greatest possible value of longitudinal defination for specified values of laboral deflection and articled bushing load, while universing the attest lovel to the columns at a rate lavel. The preferred columns, therefore, are landated, as shown in Figures 18 and 2, with exitiple flat analysis university on each column.

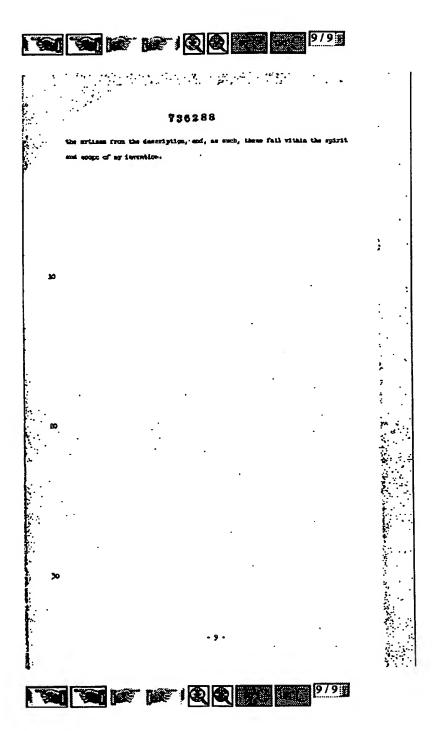
In the operation of the shows expending tool for setting a liner in well medies, the unde-up tool is lowered into the well as mentioned above, with the area 22 in the retreated position. Then the tool is at the desired level, the well taking is revolved. The friction mediar by transpar with the wall of the menting and prevents thinkle b) from revolving. With several revolutions of the totals, lower shoulder 30 is novel appearing by differential error 39 to bundle opening almost 37 which has a predefermined existent leading lead. This lead is transmitted symmity against the lower call of expender the, and its topened surface is engaged with the transmit surface on the Leade of the error 22 to orga the term extensity with a mediamically constant force proportional to the critical bundling load of the spring element. Entenometry, the expending tool is passed through the lines to expend 10 in the casing in the secont described by substant-force.

The foregoing description of a preferred embeliance of my investion has been given for the purpose of assumplification. It will be understood that various medifications in the descript of assumption will become apparent to

- 8 -

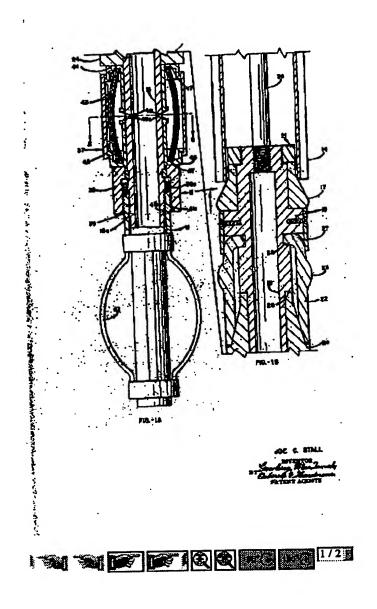
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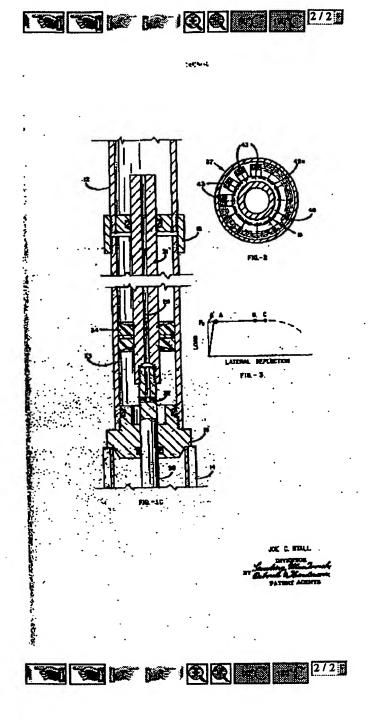






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